Table 3.--Survival and stage of development attained by brown shrimp protozoeae fed selected algae

Algae fed	Survival time	Stage of development attained 1/
	Days	
Isochrysis galbana	2	PI
Cyclotella nana	3	PI
Skeletonema costatum	4	PI
Mixture	4	PII
Thalassiosira sp.	5	PII

1/ PI is first-stage protozoeae.
PII is second-stage protozoeae.

second day, however, they appeared stronger, and brine shrimp nauplii were added. Both foods were fed throughout the remainder of the larval stages. Temperature ranged from 23° C. (73° F.) to 24° C. (75° F.), and salinity from 20.5 to 18.4 p.p.t.

The survival of the crabs in the zoeal stages was high but decreased during the megalops stage because of cannibalism. When the megalops were placed in a tank with an abundant growth of attached algae, they hid in the algae, thus reducing mortality. The young crabs would not feed on fish meal but would eat shredded fresh shrimp. The larval stage lasted about 1 month, and at the end of 2 months we had an undetermined number of crabs whose size ranged up to 10 mm. (0.5 inch) carapace width.

A small greenhouse built for the mass culturing of algae used to feed larval shrimp enabled us to begin research to find a satisfactory enrichment for growing algae in large cultures in natural sea water. We are currently investigating three methods of mass culture: (1) inducing blooms of naturally occurring phytoplankton in sea water that has been screened, but not filtered; (2) inoculating filtered and enriched sea water with several diatoms that have differing physiological requirements; and (3) making assays with several diatoms and various combinations of additives before we inoculate the large tanks.

Because of past difficulties in culturing algae in enriched sea water, we completed a series of experiments to determine if a medium made with artificial sea salts could be used. Instant Ocean[1] sea water supported growth of Skeletonema when supplemented with Tris buffer, potassium nitrate, sodium phosphate, and iron. Growth of Cyclotella required a vitamin mixture as well as the other additives.

Harry L. Cook, Project Leader

Culture of Juvenile and Adult Shrimp

Experimental rearing of penaeid shrimp in two 0.05-hectare (1/8-acre), brackish-water ponds continued this year. We distributed rice husks in one pond to increase the surface area of the bottom (thus encouraging growth of micro-organisms) and to fertilize the pond's water inexpensively. The second pond was untreated. We put about 9,000 brown shrimp postlarvae in each pond, which then had one shrimp per 0.05 $m.^2$ (0.5 $ft.^2$) of bottom. These postlarvae were reared from eggs spawned in the laboratory.

As in previous years, initially rapid shrimp growth in both ponds was followed by a period of slow growth (tables 4 and 5). Toward the end of the study, shrimp in both ponds were fed a commercially prepared rabbit "chow" at the rate of 5 percent of their body weight per day. This addition of food increased the average daily rate of growth.

Table 4.--Lengths and numbers per pound (whole shrimp) of brown shrimp held in an untreated, brackish-water pond, 1967

Date	Length				Whole shrimp per pound
	Average		Daily increment during period		
	Mm.	Inches	Mm.	Inches	Number
Apr. 28	6.5	0.26	--	--	567,500
May 18	29.3	1.15	1.14	0.044	1,892
June 15	79.9	3.14	1.81	0.071	114
July 13	87.0	3.42	0.25	0.009	91
Aug. 17 1/	80.8	3.18	-0.18	-0.007	116
Sept. 19	88.6	3.48	0.24	0.009	86

1/ Feeding began Aug. 31.

Table 5.--Lengths and numbers per pound (whole shrimp) of brown shrimp held in a fertilized, brackish-water pond, 1967

Date	Length				Whole shrimp per pound
	Average		Daily increment during period		
	Mm.	Inches	Mm.	Inches	Number
Apr. 28	6.5	0.26	--	--	567,500
May 18	26.0	1.02	0.98	0.038	2,838
June 15	75.7	2.98	1.78	0.070	126
July 13	86.1	3.39	0.37	0.014	93
Aug. 17 1/	91.8	3.61	0.16	0.006	74
Sept. 19	103.7	4.08	0.36	0.014	49

1/ Feeding began Aug. 4.

[1]Trade names referred to in this publication do not imply endorsement of commercial products.

Because of the threat of Hurricane Beulah, we harvested the shrimp prematurely on September 19, 1968, from the fertilized and untreated ponds. Shrimp in the fertilized pond attained an average total length of 103.7 mm. (4.1 inches) and a weight of 9.3 g. (0.3 ounce) over the 145-day study period. Thirty-one percent of the shrimp survived to produce an estimated projected yield of 314 kg. of tails per hectare (280 pounds per acre). Shrimp in the untreated pond attained a total length of 88.6 mm. (3.5 inches) and a weight of 5.3 g. (0.2 ounce); 23 percent survived to produce an estimated projected yield of 135 kg. per hectare (120 pounds per acre).

The low survival (31 and 23 percent) of shrimp in the ponds was attributed to oxygen depletion rather than cannibalism or disease. The levees surrounding the ponds partially obstruct the wind and thereby limit circulation and aeration. On several occasions when a bloom of phytoplankton was dense, the depletion of oxygen in the ponds caused distress and mortality among shrimp. In the future we will attempt to eliminate this cause of mortality by aerating the ponds' waters mechanically.

To gain better understanding of the ecology of the ponds as related to shrimp growth, we periodically examined water samples to determine the density of algal growth, the abundance and composition of zooplankton, and the physical and chemical conditions of the water. Also, samples of substrate were analyzed for bottom organisms. The succession of nutrients, phytoplankton, zooplankton, and populations of bottom fauna were in close agreement, but contrary to what was expected, shrimp grew best early in the study when populations of zooplankton and bottom organisms were lowest.

The abundance of organisms in our ponds tended to follow, in general, the rise and fall of the temperature during the year. Organisms were most plentiful in the summer and least abundant in the winter. The ratio between the number of bottom organisms collected in the summer and winter was 4:1; for plankters, it was 94:1.

In mid-October a single pond was stocked with about 2,900 laboratory-reared postlarvae (brown shrimp) averaging 12 mm. (0.5 inch) total length to determine their ability to overwinter. When we harvested the shrimp on May 31, we learned that 42 percent of the shrimp survived temperatures which decreased to a 3-month average low of 8.9° C. (48° F.) in January-March. Average daily growth was greatest in the spring when temperatures were increasing and least in the winter when temperatures were lowest (table 6). Burrowing was most pronounced in the winter.

Earthen levees were recently built across our two ponds to form four smaller ponds, each about 0.02 hectare (0.05 acre). The de-

Table 6.--Growth of brown shrimp stocked as postlarvae in a brackish-water pond, between October and June, 1967-68

Time period	Average water temperature		Average daily growth		Size attained during period	
Date	°C.	°F.	Mm.	Inches	Mm.	Inches
Oct. 19 to Dec. 31	21.1	70	0.43	0.017	43.7	1.72
Jan. 1 to Mar. 31	8.9	48	0.05	0.002	47.8	1.88
Apr. 1 to May 31	22.8	73	1.09	0.043	115.6	4.55

pression formed by removing soil to construct these levees created an additional pond. All ponds were drained, and we are now in the process of restocking them with brown shrimp about 75 to 100 mm. (3-4 inches) long. The purpose of this study is to find means of accelerating the growth which became slow at about this size in previous years.

Ray S. Wheeler, Project Leader

Food and Experimental Environments

To grow shrimp rapidly to maturity in artificial environments, we must know the types and amounts of food eaten and preferred by shrimp. Juvenile penaeid shrimp fed live brine shrimp (Artemia) nauplii in the laboratory decreased in growth rate after reaching 50 mm. (2 inches) total length. In pond experiments, shrimp have all but ceased growth after reaching 127 mm. (5 inches) total length. Although environmental factors such as light, salinity, oxygen level, or population density may influence the growth of shrimp, the amount and qualify of food probably have more effect. Accordingly, we began experiments during the past year to evaluate the nutritional value of prepared foods.

In our initial study with juvenile pink shrimp from Florida, a food with a fish-flour base supplemented with vitamins supported better growth (as indicated by the frequency of molting) and survival than did a diet of Artemia nauplii (fig. 1). Only 2 of 23 shrimp fed Artemia were alive at the end of 90 days; both had opaque, white flesh and were generally inactive. In contrast, 22 of 23 fed the fish flour plus vitamins survived the same period; all survivors had clear, transparent flesh, were active, and were continuing to grow.

In a second experiment, postlarval brown shrimp from Galveston Bay were fed several prepared foods containing various amounts of fish meal and vegetable flours in the form of pellets and an agar-base gel. Postlarvae fed the experimental diets did not attain the size of those fed Artemia nauplii. Foods containing large amounts of vegetable proteins--soy flour or cottonseed meal--were not eaten by either juvenile or postlarval brown shrimp. Foods